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RADIATION DOSIMETRY

BY

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RADIATION EXPOSURE - CURRENT OR PLANNED STUDIES ON RED BLOOD CELL, PLATELET AND GRANULOCYTE PRESERVATION IN NORMAL SUBJECTS AT THE NAVAL BLOOD RESEARCH LABORATORY

I. GENERAL

A. Whole body and target organ absorbed radiation dose is calculated using a formula which expresses the relationship between radiation emitted from a radionuclide localized in a source organ and that absorbed in the target organ. Total target organ absorbed radiation is the summation of the absorbed radiation from all source organs.

B. The formula is:

$$\overline{D} = \frac{\tilde{A}}{m} \sum_{i} \Delta_i \phi_i, \text{ where}$$

$\overline{D}$ is the radiation exposure to the target organ in rads

$\tilde{A}$ is the radiation in uCi-hours resulting from the fraction of the injected radionuclide localized in the source organ, corrected for physical decay and/or biologic disappearance of the isotope

$$\tilde{A} = \frac{f \times A_o}{\lambda_{physical} + \lambda_{biological}}, \text{ if}$$

f = fraction absorbed in the source organ

A_o = injected radionuclide in uCi

λ = disintegration constant = $\frac{0.693}{T\text{-}1/2}$ (physical or biological half-life) (for exponential decay)

Δ_i is the total energy emitted per ith radiation

ϕ_i is the fraction of the total energy per ith radiation emitted from the source organ absorbed by the target organ

m is the mass of the target organ

The term $\sum_i \frac{\Delta_i \phi_i}{m}$, known as the "S value", is expressed in rads/uCi-hour, and is the absorbed dose per unit cumulated activity. The S value is available for various radionuclides and source-target organ pairs of interest (See Snyder et al, Medical Internal Radiation Dose Pamphlet #11, Society of Nuclear Medicine, New York, N. Y., 1975).

C. Guidelines for radiation exposure in human experimentation have been promulgated by the Food and Drug Administration, as follows:
Title 21 - Food and Drug Administration - Part 361.1(i): "Under no circumstances may the radiation dose to an adult research subject from a single study or cumulatively from a number of studies conducted within 1 year be recognized as safe if such dose exceeds the following:"

Whole body, active blood-forming organs, lens of the eye, and gonads	rems
Single dose	3
Annual and total dose commitment	5
Other organs	
Single dose	5
Annual and total dose commitment	15

D. For gamma emitters (51-chromium, 125-Iodine, 111-Indium) 1 rad = 1 rem

II. 51-CHROMIUM RED CELL SURVIVAL

Injected = 5 uCi 51-chromium tagged red blood cells

A. 100% isotope localization in worst possible source organ, no biologic elimination of the isotope (physical half-life 51-chromium = 665 hours)

$$\tilde{A} = \frac{5 \text{ uCi}}{0.693/665 \text{ hours}} = 4.798 \times 10^3 \text{ uCi-hours}$$

1. Small intestine contents to total body $S = 6.1 \times 10^{-7}$
2. Red marrow to marrow $S = 8.5 \times 10^{-6}$
3. Testes to testes $S = 3.8 \times 10^{-4}$
4. Ovaries to ovaries $S = 1.2 \times 10^{-3}$
5. Spleen to spleen $S = 9.0 \times 10^{-5}$
6. Liver to liver $S = 1.2 \times 10^{-5}$

Calculation Results $\tilde{A} \times S$ Table I

B. Isotope source organ localization and biologic elimination based on:

1. 100% localization of injected red cell 51-chromium in the bloodstream
2. Biological half-life of labeled red cells = 720 hrs, exponential disappearance

Then $\tilde{A} = \frac{5 \text{ uCi}}{0.693/720 \text{ hours} + 0.693/665 \text{ hours}} = 2.494 \times 10^3$ uCi-hours

1. Total Body Radiation Absorbed Dose

S blood to total body = 5.0×10^{-7} rads/uCi hours

$\bar{D} = \tilde{A} \times S = 2.494 \times 10^3$ uCi-hours $\times 5.0 \times 10^{-7}$ rads/uCi-hours =

12.47×10^{-4} rads = 1.25 millirads

2. Red Marrow Radiation Absorbed Dose

S blood to marrow = 5.9×10^{-7}

$\overline{D} = (2.494 \times 10^{3})(5.9 \times 10^{-7}) = 1.47$ millirads

3. Testes Radiation Absorbed Dose

S blood to testes = 4.9×10^{-7}

$\overline{D} = 1.22$ millirads

4. Ovaries Radiation Absorbed Dose

S blood to ovaries = 5.9×10^{-7}

$\overline{D} = 1.47$ millirads

5. Spleen Radiation Absorbed Dose

S blood to spleen = 5.9×10^{-7}

$\overline{D} = 1.47$ millirads

6. Liver Radiation Absorbed Dose

S blood to liver = 5.6×10^{-7}

$\overline{D} = 1.40$ millirads

III. 125-IODINE ALBUMIN BLOOD VOLUME

Injected = 0.5 uCi 125-Iodine labeled albumin

A. 100% isotope localization in worst possible source organ, no biologic elimination of the isotope (physical half-life 125-Iodine = 1440 hours)

$$\tilde{A} = \frac{0.5 \text{ uCi}}{0.693/1440 \text{ hours}} = 1.039 \times 10^{3} \text{ uCi-hours}$$

1. Pancreas to total body $S = 1.9 \times 10^{-6}$
2. Red marrow to marrow $S = 4.4 \times 10^{-5}$
3. Testes to testes $S = 1.8 \times 10^{-3}$
4. Ovaries to ovaries $S = 5.4 \times 10^{-3}$
5. Thyroid to thyroid $S = 3.3 \times 10^{-3}$

Calculation Results - Table I

B. Isotope source organ based on 100% localization of 125-albumin in the blood, isotope elimination by physical decay only

$\tilde{A} = 1.039 \times 10^{3}$ uCi-hours

1. Blood to total body $S = 1.7 \times 10^{-6}$
2. Blood to marrow $S = 2.6 \times 10^{-6}$
3. Blood to testes $S = 1.4 \times 10^{-6}$
4. Blood to ovaries $S = 1.7 \times 10^{-6}$

Calculation Results - Table I

C. Thyroid absorbed dose based on 30% thyroid uptake of injected 125-Iodine, isotope elimination by physical decay only

1. Thyroid to thyroid $S = 3.0 \times 10^{-3}$ rads/uCi-hour

$$D = \left(\frac{30\% \ (0.5 \text{ uCi})}{0.693/1440 \text{ hrs}}\right)(3.0 \times 10^{-3} \text{ rads/uCi-hour}) = 9.35 \times 10^{-1} \text{ rads}$$

IV. 51-CHROMIUM PLATELET SURVIVAL

Injected = 30 uCi 51-chromium labeled platelets, 30 uCi free plasma 51-chromium

A. 100% isotope localization in worst possible source organ, no biologic elimination:

$$\tilde{A} = \frac{60 \text{ uCi}}{0.693/665 \text{ hours}} = 5.758 \times 10^4 \text{ uCi-hours}$$

1. Small intestine contents to total body $S = 6.1 \times 10^{-7}$
2. Marrow to marrow $S = 8.5 \times 10^{-6}$
3. Testes to testes $S = 3.8 \times 10^{-4}$
4. Ovaries to ovaries $S = 1.2 \times 10^{-3}$
5. Spleen to spleen $S = 9.0 \times 10^{-5}$
6. Liver to liver $S = 1.2 \times 10^{-5}$

Calculation Results - Table II

B. Isotope source organ localization and biological elimination based on:

1. 70% localization platelet radioactivity in blood with biologic T-1/2 = 120 hours
2. 30% localization platelet radioactivity in spleen with biologic T-1/2 = 720 hours
3. 40% localization platelet radioactivity in liver with biologic T-1/2 = 1440 hours

(See Aster and Jandl: Platelet sequestration in man. I. Methods. J. Clin. Invest. 43:843-855, 1964)

4. 30 uCi free plasma 51-chromium binding to red cells with biologic half-life = 720 hours

(the calculations which follow are not corrected for duplication)

1. Total Body Radiation Absorbed Dose

Blood to total body $S = 5.0 \times 10^{-7}$

$$\tilde{A} = \frac{70\% \text{ (30 uCi)}}{0.693/120 \text{ hours} + 0.693/665 \text{ hours}} + \frac{100\% \text{ (30 uCi)}}{0.693/720 \text{ hours} + 0.693/665 \text{ hours}}$$

$$\bar{D} = (1.804 \times 10^{4} \text{ uCi-hours})(5.0 \times 10^{-7}) = 9.02 \times 10^{-3}$$

Spleen to total body $S = 5.6 \times 10^{-7}$

$$\bar{D} = \left(\frac{30\% \text{ (30 uCi)}}{0.693/720 \text{ hours} + 0.693/665 \text{ hours}}\right)(5.6 \times 10^{-7}) = (4.489 \times 10^{3} \text{ uCi-hours})$$

$$(5.6 \times 10^{-7}) = 2.51 \times 10^{-3}$$

Liver to total body $S = 5.6 \times 10^{-7}$

$$\bar{D} = \left(\frac{40\% \text{ (30 uCi)}}{0.693/1440 \text{ hours} + 0.693/665 \text{ hours}}\right)(5.6 \times 10^{-7}) = 4.41 \times 10^{-3}$$

Total Body Radiation Absorbed Dose = blood to total body + spleen to total body + liver to total body = 15.94 millirads

2. Red Marrow Radiation Absorbed Dose

Blood to marrow $S = 5.9 \times 10^{-7}$

$$\bar{D} = (1.804 \times 10^{4})(5.9 \times 10^{-7}) = 10.64 \times 10^{-3} \text{ rads}$$

Spleen to marrow $S = 3.2 \times 10^{-7}$

$$\bar{D} = (4.489 \times 10^{3})(3.2 \times 10^{-7}) = 1.44 \times 10^{-3} \text{ rads}$$

Liver to marrow $S = 3.0 \times 10^{-7}$

$$\bar{D} = (7.879 \times 10^{3})(3.0 \times 10^{-7}) = 2.36 \times 10^{-3} \text{ rads}$$

Total Red Marrow Radiation Absorbed Dose = 14.44 millirads

3. Testes Radiation Absorbed Dose

Blood to testes $S = 4.9 \times 10^{-7}$

$\bar{D} = (1.804 \times 10^{4})(4.9 \times 10^{-7}) = 8.83 \times 10^{-3}$ rads

Spleen to testes $S = 1.9 \times 10^{-8}$

$\bar{D} = (4.489 \times 10^{3})(1.9 \times 10^{-8}) = 8.53 \times 10^{-5}$ rads

Liver to testes $S = 2.4 \times 10^{-8}$

$\bar{D} = (7.879 \times 10^{3})(2.4 \times 10^{-8}) = 18.91 \times 10^{-5}$ rads

Total Testes Radiation Absorbed Dose = 10.81 millirads

4. Ovaries Radiation Absorbed Dose

Blood to ovaries $S = 5.9 \times 10^{-7}$

$\bar{D} = (1.804 \times 10^{4})(5.9 \times 10^{-7}) = 10.6 \times 10^{-3}$ rads

Spleen to ovaries $S = 1.9 \times 10^{-7}$

$\bar{D} = (4.489 \times 10^{3})(1.9 \times 10^{-7}) = 8.53 \times 10^{-4}$

Liver to ovaries $S \doteq 9.3 \times 10^{-8}$

$\bar{D} = (7.879 \times 10^{3})(9.3 \times 10^{-8}) = 73.27 \times 10^{-5}$

Total Ovaries Radiation Absorbed Dose = 12.18 millirads

5. Spleen Radiation Absorbed Dose

Blood to spleen $S = 5.9 \times 10^{-7}$

$\bar{D} = (1.804 \times 10^{4})(5.9 \times 10^{-7}) = 10.64 \times 10^{-3}$ rads

Spleen to spleen $S = 9.0 \times 10^{-5}$

$\bar{D} = (4.489 \times 10^{3})(9.0 \times 10^{-5}) = 40.40 \times 10^{-2}$ rads

Liver to spleen $S = 2.3 \times 10^{-7}$

$\bar{D} = (7.879 \times 10^{3})(2.3 \times 10^{-7}) = 18.12 \times 10^{-4}$

Total Spleen Radiation Absorbed Dose = 417 millirads

6. Liver Radiation Absorbed Dose

Blood to liver $S = 5.6 \times 10^{-7}$

$\bar{D} = (1.804 \times 10^{4})(5.6 \times 10^{-7}) = 10.10 \times 10^{-3}$ rads

Spleen to liver $S = 2.6 \times 10^{-7}$

$\bar{D} = (4.489 \times 10^{3})(2.6 \times 10^{-7}) = 11.67 \times 10^{-4}$ rads

Liver to liver $S = 1.2 \times 10^{-5}$

$\bar{D} = (7.879 \times 10^{3})(1.2 \times 10^{-5}) = 9.45 \times 10^{-2}$ rads

Total Liver Radiation Absorbed Dose = 105.8 millirads

V. III-INDIUM PLATELET SURVIVAL

Injected = 50 uCi III-Indium labeled platelets

A. 100% isotope localization in worst possible source organ, no biologic elimination

$$\tilde{A} = \frac{50 \text{ uCi}}{0.693/67.4 \text{ hours}} = 4.863 \times 10^{3} \text{ uCi-hours}$$

1. Ovary to total body $S = 7.7 \times 10^{-6}$
2. Marrow to marrow $S = 7.5 \times 10^{-5}$
3. Testes to testes $S = 3.6 \times 10^{-3}$
4. Ovaries to ovaries $S = 1.0 \times 10^{-2}$
5. Spleen to spleen $S = 9.1 \times 10^{-4}$
6. Liver to liver $S = 1.3 \times 10^{-4}$

Calculation Results - Table II

B. Isotope source organ localization and biological elimination based on data of Aster and Jandl for 51-chromium labeled platelets

1. Total Body Radiation Absorbed Dose

Blood to total body $S = 5.8 \times 10^{-6}$

$$\tilde{A} = \frac{70\% \ (50 \text{ uCi})}{0.693/120 \text{ hours} + 0.693/67.4 \text{ hours}} = 2.180 \times 10^{3} \text{ uCi-hours}$$

$$\bar{D} = (2.180 \times 10^{3} \text{ uCi-hours})(5.8 \times 10^{-6} \text{ rads/uCi hours}) = 12.64 \times 10^{-3} \text{ rad}$$

Spleen to total body $S = 6.6 \times 10^{-6}$

$$\tilde{A} = \frac{30\% \ (50 \text{ uCi})}{0.693/720 \text{ hours} + 0.693/67.4 \text{ hours}} = 1.334 \times 10^{3} \text{ uCi-hours}$$

$$\bar{D} = (1.334 \times 10^{3})(6.6 \times 10^{-6}) = 8.80 \times 10^{-3} \text{ rads}$$

Liver to total body $S = 6.6 \times 10^{-6}$

$$\tilde{A} = \frac{40\% \ (50 \text{ uCi})}{0.693/1440 \text{ hours} + 0.693/67.4 \text{ hours}} = 1.858 \times 10^{3}$$

$\bar{D} = (1.858 \times 10^{3})(6.6 \times 10^{-6}) = 12.3 \times 10^{-3}$ rads

Total Body Radiation Absorbed Dose = 33.74 millirads

2. Red Marrow Radiation Absorbed Dose

Blood to marrow $S = 7.7 \times 10^{-6}$

$\bar{D} = (2.180 \times 10^{3})(7.7 \times 10^{-6}) = 16.79 \times 10^{-3}$ rads

Spleen to marrow $S = 4.4 \times 10^{-6}$

$\bar{D} = (1.334 \times 10^{3})(4.4 \times 10^{-6}) = 5.869 \times 10^{-3}$ rads

Liver to marrow $S = 4.1 \times 10^{-6}$

$\bar{D} = (1.858 \times 10^{3})(4.1 \times 10^{-6}) = 7.619 \times 10^{-3}$ rads

Total Marrow Radiation Absorbed Dose = 30.28 millirads

3. Testes Radiation Absorbed Dose

Blood to testes $S = 4.9 \times 10^{-6}$

$\bar{D} = (2.18 \times 10^{3})(4.9 \times 10^{-6}) = 10.68$ millirads

Spleen to testes $S = 2.0 \times 10^{-7}$

$\bar{D} = (1.334 \times 10^{3})(2.0 \times 10^{-7}) = 0.267$ millirads

Liver to testes $S = 2.5 \times 10^{-7}$

$\bar{D} = (1.858 \times 10^{3})(2.5 \times 10^{-7}) = 0.465$ millirads

Total Testes Radiation Absorbed Dose = 11.41 millirads

4. Ovaries Radiation Absorbed Dose

Blood to ovaries $S = 7.0 \times 10^{-6}$

$\bar{D} = (2.18 \times 10^{3})(7.0 \times 10^{-6}) = 15.26$ millirads

Spleen to ovaries $S = 1.7 \times 10^{-6}$

$\bar{D} = (1.334 \times 10^{3})(1.7 \times 10^{-6}) = 2.27$ millirads

Liver to ovaries $S = 1.4 \times 10^{-6}$

$\bar{D} = (1.858 \times 10^{3})(1.4 \times 10^{-6}) = 2.60$ millirads

Total Ovaries Radiation Absorbed Dose = 20.13 millirads

5. Spleen Radiation Absorbed Dose

Blood to spleen $S = 6.8 \times 10^{-6}$

$\bar{D} = (2.18 \times 10^{3})(6.8 \times 10^{-6}) = 14.82 \times 10^{-3}$ rads

Spleen to spleen $S = 9.1 \times 10^{-4}$

$\bar{D} = (1.334 \times 10^{3})(9.1 \times 10^{-4}) = 12.14 \times 10^{-1}$ rads

Liver to spleen $S = 2.8 \times 10^{-6}$

$\bar{D} = (1.858 \times 10^{3})(2.8 \times 10^{-6}) = 5.20 \times 10^{-3}$ rads

Total Spleen Radiation Absorbed Dose = 1.234 rads

6. Liver Radiation Absorbed Dose

Blood to liver $S = 6.5 \times 10^{-6}$

$\bar{D} = (2.18 \times 10^{3})(6.5 \times 10^{-6}) = 14.17 \times 10^{-3}$ rads

Spleen to liver $S = 3.0 \times 10^{-6}$

$\bar{D} = (1.334 \times 10^{3})(3.0 \times 10^{-6}) = 4.002 \times 10^{-3}$ rads

Liver to liver $S = 1.3 \times 10^{-4}$

$\bar{D} = (1.858 \times 10^{3})(1.3 \times 10^{-4}) = 2.415 \times 10^{-1}$ rads

Total Liver Radiation Absorbed Dose = 0.2597 rads

VI. III-INDIUM GRANULOCYTE SURVIVAL

Injected = 50 uCi III-Indium labeled granulocytes

A. 100% isotope localization in worst possible source organ, no biologic elimination. Calculations are those for III-Indium labeled platelet survival, Section IV. A.

Calculation Results - Table III

B. Isotope source organ localization and biologic elimination based on:

1. 100% injected granulocyte activity in bloodstream with T-1/2 = 7.5 hours
2. 25% injected activity localizes in the spleen, with isotope elimination based on physical decay only
3. 40% injected activity localizes in the liver, with isotope elimination based on physical decay only

(see Thakur et al, Indium-III-labeled autologous leukocytes in man. J. Nuc. Med. 18:1014-1021, 1977)

1. Total Body Radiation Absorbed Dose

Blood to total body $S = 5.8 \times 10^{-6}$

$$\tilde{A} = \frac{100\% \ (50 \text{ uCi})}{0.693/7.5 \text{ hours} + 0.693/67.4 \text{ hours}} = 4.869 \times 10^{2} \text{ uCi-hour}$$

$$\bar{D} = (4.869 \times 10^{2} \text{ uCi-hours})(5.8 \times 10^{-6}) = 2.824 \times 10^{-3} \text{ rads}$$

Spleen to total body $S = 6.6 \times 10^{-6}$

$$\tilde{A} = \frac{25\% \ (50 \text{ uCi})}{0.693/67.4 \text{ hours}} = 1.216 \times 10^{3} \text{ uCi-hours}$$

$$\bar{D} = (1.216 \times 10^{3})(6.6 \times 10^{-6}) = 8.024 \times 10^{-3} \text{ rads}$$

Liver to total body $S = 6.6 \times 10^{-6}$

$$\tilde{A} = \frac{40\% \text{ (50 uCi)}}{0.693/67.4 \text{ hours}} = 1.945 \times 10^{3} \text{ rads}$$

$$\bar{D} = (1.945 \times 10^{3})(6.6 \times 10^{-6}) = 12.84 \times 10^{-3} \text{ rads}$$

Total Body Radiation Absorbed Dose = 23.69 millirads

2. Marrow Radiation Absorbed Dose

Blood to marrow $S = 7.7 \times 10^{-6}$

$$\bar{D} = \tilde{A} \times S = (4.869 \times 10^{2})(7.7 \times 10^{-6}) = 37.49 \times 10^{-4} \text{ rads}$$

Spleen to marrow $S = 4.4 \times 10^{-6}$

$$\bar{D} = \tilde{A} \times S = 5.350 \times 10^{-3} \text{ rads}$$

Liver to marrow $S = 4.1 \times 10^{-6}$

$$\bar{D} = \tilde{A} \times S = 7.975 \times 10^{-3} \text{ rads}$$

Total Marrow Radiation Absorbed Dose = 50.82 rads

3. Testes Radiation Absorbed Dose

Blood to testes $S = 4.9 \times 10^{-6}$

$$\bar{D} = \tilde{A} \times S = 2.39 \times 10^{-3} \text{ rads}$$

Spleen to testes $S = 2.0 \times 10^{-7}$

$$\bar{D} = \tilde{A} \times S = 0.243 \times 10^{-3} \text{ rads}$$

Liver to testes $S = 2.5 \times 10^{-7}$

$$\bar{D} = \tilde{A} \times S = 0.486 \times 10^{-3} \text{ rads}$$

Total Testes Radiation Absorbed Dose = 3.12 millirads

4. Ovaries Radiation Absorbed Dose

Blood to ovaries $S = 7.0 \times 10^{-6}$

$\bar{D} = \tilde{A} \times S = (4.869 \times 10^{2})(7.0 \times 10^{-6}) = 3.41 \times 10^{-3}$ rads

Spleen to ovaries $S = 1.7 \times 10^{-6}$

$\bar{D} = \tilde{A} \times S = (1.216 \times 10^{3})(1.7 \times 10^{-6}) = 2.07 \times 10^{-3}$ rads

Liver to ovaries $S = 1.4 \times 10^{-6}$

$\bar{D} = \tilde{A} \times S = (1.945 \times 10^{3})(1.4 \times 10^{-6}) = 2.73 \times 10^{-3}$ rads

Total Ovaries Radiation Absorbed Dose = 8.21 millirads

5. Spleen Radiation Absorbed Dose

Blood to spleen $S = 6.8 \times 10^{-6}$

$\bar{D} = \tilde{A} \times S = (4.869 \times 10^{2})(6.8 \times 10^{-6}) = 3.31 \times 10^{-3}$ rads

Spleen to spleen $S = 9.1 \times 10^{-4}$

$\bar{D} = \tilde{A} \times S = (1.216 \times 10^{3})(9.1 \times 10^{-4}) = 11.07 \times 10^{-1}$ rads

Liver to spleen $S = 2.8 \times 10^{-6}$

$\bar{D} = \tilde{A} \times S = (1.945 \times 10^{3})(2.8 \times 10^{-6}) = 5.45 \times 10^{-3}$ rads

Total Spleen Radiation Absorbed Dose = 1.12 rads

6. Liver Radiation Absorbed Dose

Blood to liver $S = 6.5 \times 10^{-6}$

$\bar{D} = \tilde{A} \times S = (4.869 \times 10^{2})(6.5 \times 10^{-6}) = 3.17 \times 10^{-3}$ rads

Spleen to liver $S = 3.0 \times 10^{-6}$

$D = A \times S = (1.216 \times 10^{3})(3.0 \times 10^{-6}) = 3.65 \times 10^{-3}$ rads

Liver to liver $S = 1.3 \times 10^{-4}$

$D = A \times S = (1.945 \times 10^{3})(1.3 \times 10^{-4}) = 2.53 \times 10^{-1}$ rads

Total Liver Radiation Absorbed Dose = 260 millirads

VII. 51-CHROMIUM GRANULOCYTE SURVIVAL

Injected = 30 uCi 51-chromium labeled granulocytes, 30 uCi free plasma 51-chromium

A. 100% isotope localization in worst possible source organ, no biologic elimination. Calculations are those for 51-chromium platelet survival, Section III. A.

Calculation Results - Table III

B. Isotope source organ localization and biologic elimination based on Thakur data for III-Indium labeled granulocytes; 30 uCi free plasma 51-chromium binding in vivo to red cells, with biologic half-life = 720 hours

1. Total Body Radiation Absorbed Dose

Blood to total body $S = 5.0 \times 10^{-7}$

$$\tilde{A} = \frac{30 \text{ uCi}}{0.693/7.5 \text{ hours} + 0.693/665 \text{ hours}} + \frac{30 \text{ uCi}}{0.693/720 \text{ hours} + 0.693/665 \text{ hours}}$$

$= 321.1 \text{ uCi-hours} + 1.496 \times 10^4 \text{ uCi-hours} = 1.529 \times 10^4 \text{ uCi-hours}$

$\bar{D} = \tilde{A} \times S = (1.529 \times 10^4)(5.0 \times 10^{-7}) = 7.65 \times 10^{-3}$ rads

Spleen to total body $S = 5.6 \times 10^{-7}$

$$\tilde{A} = \frac{25\% \text{ (30 uCi)}}{0.693/665 \text{ hours}} = 7.197 \times 10^3 \text{ uCi-hours}$$

$\bar{D} = A \times S = (7.197 \times 10^3)(5.6 \times 10^{-7}) = 4.031 \times 10^{-3}$ rads

Liver to total body $S = 5.6 \times 10^{-7}$

$$\tilde{A} = \frac{40\% \text{ (30 uCi)}}{0.693/665 \text{ hours}} = 1.152 \times 10^4 \text{ uCi-hours}$$

$\bar{D} = \tilde{A} \times S = (1.152 \times 10^{4})(5.6 \times 10^{-7}) = 6.45 \times 10^{-3}$ rads

Total Body Radiation Absorbed Dose = 18.13 millirads

2. Red Marrow Radiation Absorbed Dose

Blood to marrow $S = 5.9 \times 10^{-7}$

$\bar{D} = \tilde{A} \times S = (1.529 \times 10^{4})(5.9 \times 10^{-7}) = 9.02 \times 10^{-3}$ rads

Spleen to marrow $S = 3.2 \times 10^{-7}$

$\bar{D} = \tilde{A} \times S = (7.197 \times 10^{3})(3.2 \times 10^{-7}) = 2.31 \times 10^{-3}$ rads

Liver to marrow $S = 3.0 \times 10^{-7}$

$\bar{D} = \tilde{A} \times S = (1.152 \times 10^{4})(3.0 \times 10^{-7}) = 3.45 \times 10^{-3}$ rads

Total Marrow Radiation Absorbed Dose = 14.8 millirads

3. Testes Radiation Absorbed Dose

Blood to testes $S = 4.9 \times 10^{-7}$

$\bar{D} = \tilde{A} \times S = (1.529 \times 10^{4})(4.9 \times 10^{-7}) = 7.49 \times 10^{-3}$ rads

Spleen to testes $S = 1.9 \times 10^{-8}$

$\bar{D} = \tilde{A} \times S = (7.197 \times 10^{3})(1.9 \times 10^{-8}) = 0.137 \times 10^{-3}$ rads

Liver to testes $S = 2.4 \times 10^{-8}$

$\bar{D} = \tilde{A} \times S = (1.152 \times 10^{4})(2.4 \times 10^{-8}) = 0.276 \times 10^{-3}$ rads

Total Testes Radiation Absorbed Dose = 7.91 millirads

4. Ovaries Radiation Absorbed Dose

Blood to ovaries $S = 5.9 \times 10^{-7}$

$\bar{D} = \tilde{A} \times S = (1.529 \times 10^{4})(5.9 \times 10^{-7}) = 9.02 \times 10^{-3}$ rads

Spleen to ovaries $S = 1.9 \times 10^{-7}$

$\bar{D} = \tilde{A} \times S = (7.197 \times 10^{3})(1.9 \times 10^{-7}) = 0.137 \times 10^{-3}$ rads

Liver to ovaries $S = 9.3 \times 10^{-8}$

$\bar{D} = \tilde{A} \times S = (1.152 \times 10^{4})(9.3 \times 10^{-8}) = 1.07 \times 10^{-3}$ rads

Total Ovaries Radiation Absorbed Dose = 10.22 millirads

5. Spleen Radiation Absorbed Dose

Blood to spleen $S = 5.9 \times 10^{-7}$

$\bar{D} = \tilde{A} \times S = (1.529 \times 10^{4})(5.9 \times 10^{-7}) = 9.021 \times 10^{-3}$ rads

Spleen to spleen $S = 9.0 \times 10^{-5}$

$\bar{D} = \tilde{A} \times S = (7.197 \times 10^{3})(9.0 \times 10^{-5}) = 647.8 \times 10^{-3}$ rads

Liver to spleen $S = 2.3 \times 10^{-7}$

$\bar{D} = \tilde{A} \times S = (1.152 \times 10^{4})(2.3 \times 10^{-7}) = 2.650 \times 10^{-3}$ rads

Total Spleen Radiation Absorbed Dose = 659.5 millirads

6. Liver Radiation Absorbed Dose

Blood to liver $S = 5.6 \times 10^{-7}$

$\bar{D} = \tilde{A} \times S = (1.529 \times 10^{4})(5.6 \times 10^{-7}) = 8.56 \times 10^{-3}$ rads

Spleen to liver $S = 2.6 \times 10^{-7}$

$\bar{D} = \tilde{A} \times S = (7.197 \times 10^{3})(2.6 \times 10^{-7}) \simeq 18.71 \times 10^{-3}$ rads

Liver to liver $S = 1.2 \times 10^{-5}$

$\bar{D} = \tilde{A} \times S = (1.152 \times 10^{4})(1.2 \times 10^{-5}) = 1.383 \times 10^{-1}$ rads

Total Liver Radiation Absorbed Dose = 165.6 millirads

TABLE 1

51-CHROMIUM RED BLOOD CELL SURVIVAL, 125-IODINE BLOOD VOLUME

ORGAN RADIATION ABSORBED DOSE

	Target Organ	Assumptions: Worst Possible Source Organ Isotope Localization, No Biologic Elimination (RADS)	Assumptions: Effective Kinetics of Isotope (RADS)
51-Chromium Red Cell Survival (5 uCi)	Total Body	0.003	0.0013
	Marrow	0.041	0.0015
	Testes	1.82	0.0012
	Ovaries	5.76	0.0015
	Spleen	0.432	0.0015
	Liver	0.058	0.0014
125-Iodine Blood Volume (0.5 uCi)	Total Body	0.0020	0.0018
	Marrow	0.0457	0.0027
	Testes	1.870	0.0015
	Ovaries	5.611	0.0018
	Thyroid	3.429	0.935*

*Based on calculations in Section III (C).

TABLE II

51-CHROMIUM PLATELET SURVIVAL AND III-INDIUM PLATELET SURVIVAL

ORGAN RADIATION ABSORBED DOSE

	Target Organ	Assumptions: Worst Possible Source Organ Isotope Localization, No biologic Elimination (RADS)	Assumptions: Effective Kinetics of Isotope (RADS)
51-Chromium Platelet Survival (60 uCi)	Total Body	0.035	0.016
	Marrow	0.489	0.014
	Testes	21.9	0.011
	Ovaries	69.1	0.012
	Spleen	5.18	0.417
	Liver	0.691	0.106
III-Indium Platelet Survival (50 uCi)	Total Body	0.037	0.034
	Marrow	0.365	0.030
	Testes	17.5	0.011
	Ovaries	48.6	0.020
	Spleen	4.43	1.240
	Liver	0.632	0.260

TABLE III

51-CHROMIUM GRANULOCYTE SURVIVAL AND III-INDIUM GRANULOCYTE SURVIVAL

ORGAN RADIATION ABSORBED DOSE

	Target Organ	Assumptions: Worst Possible Source Organ Isotope Localization, No biologic Elimination (RADS)	Assumptions: Effective Kinetics of Isotope (RADS)
51-Chromium Granulocyte Survival (60 uCi)	Total Body	0.035	0.0182
	Marrow	0.489	0.0148
	Testes	21.9	0.0079
	Ovaries	69.1	0.0010
	Spleen	5.18	0.6595
	Liver	0.691	0.1656
III-Indium Granulocyte Survival (50 uCi)	Total Body	0.037	0.0237
	Marrow	0.365	0.0508
	Testes	17.5	0.0032
	Ovaries	48.6	0.0082
	Spleen	4.43	1.12
	Liver	0.632	0.260